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PROFESSOR GEIKIE'S CLASSIFICATION OF THE
NORTH EUROPEAN GLACIAL DEPOSITS.

IN Vol. III of this JOURNAL, Professor James Geikie gives a concise account of his present ideas concerning the classification of the north European glacial formations. His statement involves a comparison of the drift formations of various north European localities with one another, and with those of the Alps. He differentiates six glacial epochs, separated by five interglacial epochs, which he names after typical localities, as follows :

First glacial epoch, Scanian.

First interglacial epoch, Norfolkian or *Elephas meridionalis* stage.

Second glacial epoch, Saxonian.

Second interglacial epoch, Helvetian or *Elephas antiquus* stage.

Third glacial epoch, Polandian.

Third interglacial epoch, Neudeckian.

Fourth glacial epoch, Mecklenburgian.

Fourth interglacial epoch, Lower Forestian.

Fifth glacial epoch, Lower Turbarian.

Fifth interglacial epoch, Upper Forestian.

Sixth glacial epoch, Upper Turbarian.

1. *Scanian stage*.—The oldest glacial formation of north Europe appears in Schonen and points to a Baltic glacier. In England perhaps the Chillesford Clay and Weybourn Crag with
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their arctic molluscan fauna belong to this stage. Here also Geikie places the oldest Alpine glacial deposits as well as the old "Diluvium" of the plateau of central France. In another part of his work he expresses the opinion that the oldest ground moraine in the Baltic region of Germany belongs to this stage.

2. *Norfolkian*.—To this stage belongs the Forest bed of Norfolk, during the formation of which a climate prevailed at least as temperate as that of today. In Alpine districts the lignite of Leffe and elsewhere, as well as the interglacial deposits of the Hötting breccia, indicating a climate warmer than that of the present day, correspond to this stage.

3. *Saxonian*.—In this epoch the ice reached its greatest expansion. In north Europe the formations of this epoch extend to the borders of the Carpathians, the Sudetic Mountains, the Erzgebirge and the Thuringian Mountains. In the Alps, the corresponding formation covers a more extensive area than that of the Scanian epoch, while in Great Britain the corresponding sheet of drift is more widespread than that of any preceding or following epoch. To this stage belongs the lower boulder clay of the British Isles, the Lower Diluvium of Holland and north Germany, the outer moraines and the associated gravels of Alpine lands, as well as the older moraines of the numerous mountain chains of middle and southern Europe.

4. *Helvetian*.—The character of the flora and fauna is variable, being here more arctic and there more temperate. To this stage belongs the interglacial deposits in Lanarkshire, Ayrshire, Edinburghshire, etc., and the Hessle gravels of East Anglia, the beach deposits of Sussex, and certain cave accumulations of mammalian remains, the interglacial beds of Holstein and Kottbus, the sands of Rixdorf, the interglacial beds of Moscow the interglacial deposits of Cantal, as well as numerous old river deposits of the Thames, Seine, Rhine, etc.

5. *Polandian*.—To this stage belong the glacial and fluvio-glacial deposits of a Scandinavian *mer de glace*, which was smaller than the second, and the similar deposits of Great

Britain, the Alps and other districts. This stage includes the upper boulder clay of the British Islands, the Upper Diluvium of central north Germany, Poland and central west Russia, the ground and terminal moraines of the "inner zone" of the Alps, together with the attendant gravels, and the younger valley moraines in various mountain chains.

6. *Neudeckian*.—The deposits of this interglacial stage are best observed in the southern coast lands of the Baltic. They originated partly in salt, and partly in fresh water, and are intercalated between two ground moraines, which are designated the lower and upper boulder clay respectively. The fauna points to a temperate, not to an arctic climate.

7. *Mecklenburgian*.—To this stage belong the ground moraines and end-moraines of the latest Baltic glacier, and it reaches its southern extremity in the terminal moraine of the Baltic *Höhenrücken*. Of the same age as these north German deposits (Upper Diluvium of northern north Germany) are the moraines of the first postglacial stage in the Alps, the great valley glaciers of the British Islands, the Yoldia deposits of Scandinavia, the 100-foot beach of Scotland with its arctic fauna, and certain arctic plant beds below the Turbaries of Great Britain, Denmark and Scandinavia.

8. *Lower Forestian*.—To this stage belong the deposits of the large fresh water lake (Ancyclus-beds) filling a part of the basin of the Baltic, the older buried forests under the peat bogs of northwest Europe, and to some extent the Scandinavian Littorina beds. In the Alps no equivalent is known. The land in Europe possessed at that time a greater extent and a warmer climate than at the present day.

9. *Lower Turbarian*.—Marked by expansion of the sea, moister and colder climate, glacial formations in Scotland and Norway, where some of the valley glaciers extended to the sea, though most terminated at a considerable distance from it. In the Alps, the deposits of the second postglacial stage, the moraines situated in the inner valleys, correspond to this stage. This stage is represented in Britain by certain peat beds, in

Scandinavia by calcareous tufa, and certain *Littorina* beds and in Scotland by beach lines.

10. *Upper Forestian*.—In northwestern Europe a second forest bed, overlying 8, represents this stage. The area of land is greater than in the preceding glacial stage, but is still less than in the preceding interglacial epoch. The flora and fauna indicate a temperate climate drier than that of the 9th stage.

11. *Upper Turbarian*.—Characterized by a new advance of the sea on the land. The shores are no longer reached by the ice, but it is highly probable that the moraines in the upper parts of the valleys of Scotland and Norway, and belonging to the last glacial period, are of the same age as the lower beach lines. With the close of this glacial epoch recent conditions begin.

This is the new scheme by which Geikie would correlate the whole of the European glacial deposits, The following is given in tabular form, for the sake of simplicity.

Stage.	Great Britain.	Scandinavia.	Alps.	North Germany.
1.	Chillesford clay. Weybourn crag.	Deposits of the oldest Baltic glaciers in Schonen.	Oldest ground-moraine of the Baltic.	<i>Deckenschotter</i> and moraines belonging to it.
2.	Forest-bed of Norfolk.			Lignite of Lefte. Hötting breccia.
3.	Lower Boulder clay.	Moraines and fluvio-glacial formations.	Lower Diluvium.	Outer moraine. High terrace gravels.
4.	Marine deposits of Lanarkshire, Ayrshire, etc.; Hessle gravel, beach deposits of Sussex.			Peat bed in Holstein and Lignites of Switzerland and Altgau near Kottbus. Sands of Rixdorf.
5.	Upper boulder clay.		Inner moraine and lower terrace gravels.	Upper Diluvium south of the Baltic terminal moraine.

Stage.	Great Britain.	Scandinavia.	Alps.	North Germany.
6.				Marine deposits in West Prussia.
7.	Valley glaciers and 100-foot beach of Scotland.	Yoldia clay.	Moraines of the first post-glacial stage.	Upper Diluvium north of the Baltic terminal moraine.
8.	Lower forest-bed.	Ancylus beds, Littorina beds (in part).		
9.	Terminal moraines in the valleys.	Littorina beds (in part).	Moraines of the second post-glacial stage.	
10.	Upper forest bed.			
11.	Terminal moraines in the upper parts of the valleys.			

The high authority of Professor Geikie on all questions concerning the European Ice Age has caused this classification, of the correctness of which Geikie himself is not thoroughly assured, to be received and used as final by many German writers who are not in a position thoroughly to appreciate the significance of the questions involved. Thus R. Credner¹ writes:

Folgen wir den Anschauungen, zu welchen neuerlich einer der hervorragendsten Glacialgeologen James Geikie, auf Grund vergleichender Untersuchungen sämtlicher europäischer Vergletscherungsgebiete, vor Allem der britischen, der alpinen und der skandinavischen, gelangt ist, so haben wir für unser baltisches Becken vier durch Interglacialzeiten von einander getrennte Eisausbreitungen anzunehmen; und . . . es entstand schliesslich, den Rand des letzten baltischen Eisstromes andeutend, der Zug echter Endmoränen, welcher in Gestalt wallartig gestalteter Blockschüttungen nördlichen Ursprunges von Preussen bis nach Schleswig-Holstein hinein den Landrücken krönt.

In opposition to the preceding, and in full concert with my colleague in the Royal Prussian Geological Survey, who with me is

¹ Entstehung der Ostsee, pp. 540 and 646.

concerned in the geological exploration and mapping of the north German plain, I am bound to say that the fourfold classification of the north German glacial formations, given by Geikie, in no way corresponds to our observations, nor to the statements published in the "Explanations to the geological special map of Prussia and the Thuringian states," or in the annual report of the Royal Prussian Geological Survey, and in other places. After many years of careful work in the territory referred to, we find no conclusive reason for ascribing the ground moraine, designated by us as the upper boulder clay, to more than one ice epoch. On the contrary, all of my colleagues who are or were occupied in the territory of the terminal moraine of the Baltic range, are, like myself, firmly of the opinion that the youngest ground moraine in front of and behind the terminal moraine, was deposited at one and the same time, by one and the same *mer de glace* distinct from and younger than that which deposited the upper boulder clay of the territory of middle north Germany.

I must next consider the reasons which guided Geikie in his reference of the Upper Diluvium (drift) of north Germany to two glacial periods. They are stated in the second edition of the *Great Ice Age*, and seem to me to be essentially traceable to the four following points of view :

1. In different localities the ground moraine of the epoch of most extensive glaciation (Saxonian stage) contains (on account of the different directions of movement, radiating from the north of Scandinavia) boulders quite different from the ground moraine of the younger inland *mer de glace*, which moved in the direction of the Baltic. According to Zeise the lower ground moraine of Schleswig-Holstein, is, so far as concerns its constitution, in no way different from the lower ground moraine of the moraine district, so the former cannot be the equivalent of the lower boulder clay of the Mark, Posen, etc.

2. In Finland two systems of glacial striæ are developed ; an older one, which thus far has been observed only outside the territory enclosed by the terminal moraine, and a younger one

which thus far has been observed only inside the territory enclosed by the terminal moraine. The latter owes its formation to a glacier which moved in the direction of the Baltic, and which cannot have exceeded the line occupied by the terminal moraine. The ground moraines before and behind this moraine must belong to two different ice epochs.

3. The upper boulder clay of Great Britain contains Scandinavian boulders, and the Scandinavian *mer de glace*, in this third ice epoch came in contact with the Scottish one. But the ice depositing the Upper Diluvium of the Cimbric peninsula did not quite reach the North Sea; therefore this Upper Diluvium cannot be of the same age as the Scottish Diluvium of the third ice period, but must belong to a later fourth ice period. We come now to a comparison, if we suppose that the terminal moraine of the Baltic range represents the outermost edge of an independent glaciation, differing in point of time from that left behind by the Upper Diluvium of middle north Germany.

4. The separation is also shown by the appearance of the interglacial formations at Neudeck in West Prussia.

On the other hand we must remark (1) that continual study of boulders in the different ground moraines has convinced German geologists, more and more, that no fundamental difference in this respect, is to be found; that, in other words, no single stone can be considered as a guide stone of the ground moraine of a definite ice epoch throughout the whole of its duration. Therefore we must form no far reaching conclusion from the local differences between boulders belonging to two ground moraines lying one over the other.

2. Geikie believes that the Finnish terminal moraine is identical in point of time with that of the Baltic range. The line of union which he draws from east Prussia to Finland is, to my knowledge, purely hypothetical, and supported by no observations. I look for the easterly continuation of the Baltic terminal moraine much farther south, in the interior of Russia, and am of the opinion that the Finnish terminal moraine belongs with that

of middle Sweden and southern Norway, a view which is shared by Herr Vogt in Christiania.

3. It seems to me unnecessary entirely to repudiate the opinions of the north-German geologists in order to explain the occurrence of Scandinavian boulders in the upper boulder clay of Great Britain. It remains also to be proved that these Scandinavian boulders have not been taken from the terminal moraines of the second ice period and incorporated in the drift of the third, and it may also be questioned whether the ground moraine of Scotland with northern boulders really belongs altogether to the third glacial period, or whether the connection of the Scandinavian with the Scottish ice in the third glacial period is more than imaginary. I am prompted to raise these questions, because there are extremely weighty reasons against the acceptance of the Baltic terminal moraine as the outermost extremity of a separate (fourth) glacial epoch. On the contrary, the similarity in age of this moraine with the so-called upper boulder clay of the Mark, Posen, etc., seems undisputed. I will state these reasons more definitely.

Of the terminal moraine of the Mark-Brandenburg, seventy-five square kilometers have been carefully mapped (scale 1:25,000) by the geological survey, and the investigation and surveying of the bordering territory on both sides reaches almost to Stettiner Haff in the north, and nearly to the northern edge of Lausitz in the south; therefore the territory investigated stretches in round numbers seventy-five kilometers from the terminal moraine in both directions. I have myself mapped a strip of country in the territory of the Baltic range between the Oder and Vistula extending thirty-four kilometers from east to west, and 100 kilometers from north to south. The terminal moraine passes through this strip for a distance of forty-five kilometers, and a territory twelve to twenty-four kilometers in breadth south of the terminal moraine is included within it. I have also by general surveying of the 500 kilometers of terminal moraine between the Oder and the Vistula, crossed the range in many places. All this work, and particularly the special mapping of about

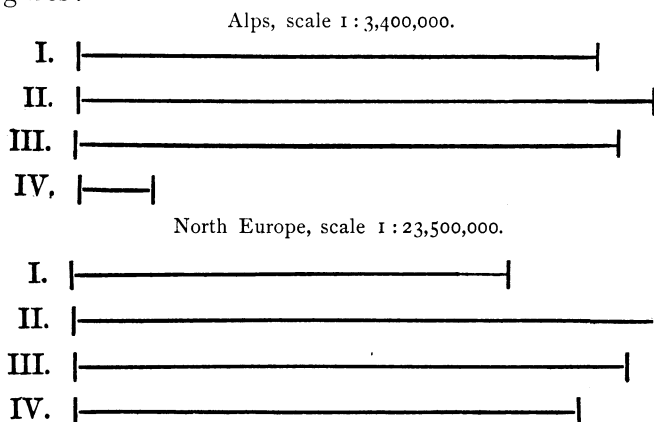
150 field sheets (1:25,000) has now shown that the uppermost boulder clay north and south of the terminal moraine are identical, that they belong to one glacial epoch, and that one sees in the terminal moraine¹ not the external margin, but only a stage of retreat of the latest glacier of these countries. In numerous places the ground moraine passes smoothly under the terminal moraine and in this manner several bridges are formed between the inner and outer ground moraine, and their identity is so firmly established, that stronger arguments than Geikie's are required to overturn the results of long years of careful, special inquiry. Those parts of the ground moraine passing under the terminal moraine are joined together in large masses to the north and south with the extensive ground moraines which Geikie maintains belong to two different ice epochs.

4. By mentioning as proof of his position, the existence of marine interglacial formations at Neudeck in West Prussia, Geikie plainly reaches a false conclusion, for he assumes what has still to be proven, that the last ground moraine but one of Neudeck is of the same age as the last (uppermost) ground moraine south of the Baltic. Without this proof the marine layers of Neudeck have no demonstrative significance, especially as their underlying beds are not known, and no observations have been made as to the number of ground moraines beneath them. Granted, however, that Geikie's view is right, that the Baltic terminal moraine is the southern limit of a distinct glaciation, one cannot understand why each of the other terminal moraines of north Germany may not also represent the edge of the ice during a distinct glacial period. On this basis the so-called "last glacial epoch" would have to be divided into four if not five epochs, so that even the most fanatical advocate for as many glacial periods as possible would be terrified.

I see a farther argument against Geikie's classification in the great difficulties of his comparison and in the inequality of the layers placed in the same stage. While with regard to the older

¹ I think Dr. Keilhack here uses "terminal moraine" in the German, not in the American sense (see p. 136 this number of this JOURNAL). R. D. S.

glacial periods there is a satisfactory conformity between the ice expansions of Great Britain and those of north Europe and the Alps, such conformity is altogether wanting in Geikie's assumed fourth epoch. The Baltic glacier supposed by him to belong to the fourth period is still of such immense size, and is so little inferior to those of the earlier epochs, that it is almost impossible to correlate it with the valley glaciers of the Alps which Penck has described, and it seems to me with perfect right, as representing only postglacial episodes. Hensen has regarded the similar deposits of Norway as epiglacial projections of existing glaciers. A graphic representation, such as that of Fig. 1 shows better than words can, the unnaturalness of Geikie's classification. If we suppose the expansion of the north European and Alpine glaciations to be expressed by lines which represent the extent of glaciation from the northern end of the Gulf of Bothnia, and from the central Alps respectively, and if the lines which represent the greatest extremity of ice be represented by unity in both cases, we obtain the proportions expressed by the following figures :



If, however, one considers the Baltic terminal moraine as well as all others which lie further south, only as stages in the retreat of a single ice-sheet, as the Prussian Geological Survey has done, and so unites Geikie's No. 3 and No. 4 into No. 3, all difficulties of comparison at once disappear. 1, 2 and 3, in north

Europe correspond respectively with 1, 2 and 3 in the Alps, and the small extension of ice in the fourth and fifth ice epochs, recognizable in the Alps, Norway, and Scotland, and of approximately equal extent, are represented in north Germany, not by the reappearance of a *mer de glace*, but by climatic depressions only.

On the other hand I can agree with Geikie in his view that the principal glacial period (Saxonian stage) is the second glacial epoch, which had a predecessor in the so-called Scanian stage. The undeniable proof of three extensive glaciations of the Alps must awaken the suspicion that the north European glacial period also possesses a threefold division, and this suspicion would be increased still more in the mind of the present writer, by a number of other phenomena. The reason, however, why the special surveying has so far produced no conclusive evidence of a pre-Saxonian glacial period, lies simply in the fact that the mapping has been confined almost exclusively to districts in which no ground moraines of the inland ice of the Scanian stage exists, but where the deposits of this epoch are almost exclusively fluvio-glacial, and these for the most part fine. It is known, moreover, that such formations in north Germany found due appreciation much later than those in the Alps, and that today even eminent geologists, such as H. Credner, will not acknowledge that they possess any demonstrative power. What has led me to recognize in the lower sands and clays of the Diluvium of middle north Germany the fluvio-glacial equivalent of a glacial period older than that which deposited the lower boulder clay of the Mark, is the fact that between these layers are to be found a flora and fauna which point to a mild, temperate climate like that of today, if not indeed a warmer one. Because, however, the underlying layers contain certain northern material, such as feldspar, fragments of bryozoans, flints, and occasionally even large boulders, the conclusion is not to be gainsaid that the ice lay at no very great distance from the territories in which those northern sands were deposited. The superimposed layers, however, contain a forest vegetation with deciduous trees, a water vegetation with plants of southerly

character, such as *Trapa natans*, and even *Cratopleura*. Such, however, can never thrive in a flat country, if the latter is partly covered with glacier ice and the climate of that country arctic. Therefore a period with a warm climate must necessarily have existed between the deposition of the oldest northern sands and those of the ground moraine of the lower boulder clay, and therefore for north Germany a third oldest period must be assumed besides the two glacial periods which deposited the upper and lower boulder clay. The ground moraines of this oldest glacial period I recognize not only in Schonen, but also in the deepest ground moraines of the Baltic range, especially in that part of it lying to the east of the Oder. On the other hand, no observations have hitherto been made which point to an extension of these ground moraines in the district south of the range.

If I attempt at the conclusion of these remarks, which I consider necessary for the verification and defense of the standpoint adopted in the official survey in north Germany, to give a classification of the north German diluvial deposits in tabular form, I beg that this attempt may be considered only as a private opinion, which I should like to submit to a wider circle, for criticism and examination.

Preglacial.—Not yet determined with certainty. No deposits between the Miocene and the first glacial epoch certainly recognized.

First glacial epoch.—Oldest ground moraines in the region of the east Baltic Lake district. Fluvio-glacial formations, reaching to Hanover, and the southern part of the Mark, *e. g.*, the sands under the deposits of the first interglacial period.

First interglacial epoch.—Clays and marls rich in *Paludina* (*Paludina* deposits) in the understratum of Berlin. Peat of Klinge near Kottbus. Fresh water lime of the Flaming (Belzig, Görzke, Ziesar) and of the heath of Lüneberg. Diatomaceous layers of the Soltau, Oberohe and Rathenow. *Yoldia* clay in West Prussia, *Cyprina* clay in Holstein, fauna of Burg in western Holstein, *Cardium* sands of Lauenburg, etc.

Second glacial epoch.—Lower boulder clay of north Germany. Red boulder clay of the Altmark; numerous fluvio-glacial sands and clay (Glindower clay) under and over it.

Second interglacial epoch.—Mammalian fauna of Rixdorf, marine and fresh water deposits of west and east Prussia, oyster-banks of Slade, Blankanese, Fahrenkrug; peat of Lauenburg, Beldorf, Fahrenkrug, and elsewhere. Calcareous tufas of Madgeburg, fresh water formations of Rathenow and the district of Potsdam.

Third glacial epoch.—Upper boulder clay of north Germany. Terminal moraines of the Baltic Range and more southerly districts. Valley sands of the great valleys and ice-dammed seas. Clayey deposits (valley clay, *Deckthon*).

Postglacial epoch.—Arctic flora beyond the north German Turbaries.

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